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ADVANCED SOLAR ENERGY CONVERSION

Annual Progress Report

NASA Cooperative Agreement NCCI-8
September 1, 1980 to August 31, 1981

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Advanced Solar Energy Conversion

NCCI-8, 9/1/80 to 8/31/81

SUMMARY

During the reporting period an important breakthrough experiment has been made for the concept of direct solar-pumped gas lasers. An atomic iodine laser, a candidate for the direct solar-pumped lasers, was successfully excited with a 4-kW beam from a xenon arc solar simulator, thus for the first time the feasibility of the concept was proved experimentally beyond any doubt. The experimental set up, the laser output as functions of operating conditions are presented.

Included also in the report are the preliminary results of the iodine laser amplifier pumped with the HCP array to which a Q-switch for giant pulse production was coupled. Two invention disclosures "Laser-Driven MHD Generator for Conversion of Laser Energy to Electricity" and "Solar-Pumped Gas Lasers" were made during the reporting period.

Advanced Solar Energy Conversion
NCCI-8
September 1, 1980-August 31, 1981

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I. INTRODUCTION

This annual report covers the period from September 1, 1980 to August 31, 1981 of the NASA Cooperative Agreement NCCI-8 entitled "Advanced Solar Energy Conversion".

The report includes 1) the description of the solar-pumped gas laser experiment which proved for the first time the feasibility of a high-power space solar laser, 2) the preliminary result of the HCP-plasma pumped iodine-laser amplifier experiment, and 3) the evaluation of a laser MHD generator concept proposed as an advanced laser power converter.

Since the details of the above investigations have already been reported jointly with the Center's staff elsewhere, only brief descriptions are provided here.

II. SOLAR-PUMPED LASER EXPERIMENT

The experimental set-up for solar-pumped lasers is shown in Figure 1. A 50-kW solar simulator which has up to a 5-kW beam power output in a spectral profile similar to the air mass zero (AMO) solar spectrum was used as the light source. The average spectral deviation is $\pm 5\%$, and the maximum (in visible) is $\pm 40\%$. The deviation for the band $.25 \sim .29 \mu\text{m}$ has not been accurately determined. The beam power output was measured with a circular foil heat-flux gage. The 4-kW beam power radiated from the 600-amp xenon arc in the simulator was mainly used for the experiment although the beam power was varied as needed. The laser system includes the reflecting cone, the laser cavity, and an optical chopper. The laser system is one of side-on pumping arrangements, and the laser output was measured with a Ge detector without a preamplifier. The optical chopper placed near the focus of the beam enables pulsed pumping. An illumination risetime as short as 1 ms was obtained with the chopper. This was necessary to reach the laser threshold before the build-up of I_2 , a strong quenching agent appearing in the iodine laser kinetics.

Figure 2 shows the block diagram of the experimental set-up. Electrical and optical couplings of the components are indicated by the solid and dotted lines. The components are identified in the blocks. Synchronization of the pumping beam and the detecting system is accomplished by a photoelectric eye located behind the chopper.

Figure 3 shows the color temperature of the solar simulator spectrum determined by calibrating the beam intensity with a standard-carbon arc spectrum for which absolute intensity is known. A noon-time solar spectrum near the laboratory is also shown for comparison. To minimize the experimental error both spectra were obtained via identical optical paths. A 1/2-m McPherson monochrometer was operated in a scanning mode. The spectra were digitized and analyzed with HP 9845 calculator. As indicated, the color temperature of the simulator beam is 5,815K while the noon-time solar spectrum is 5,560K. Since the AMO solar spectrum in

outer space is known to be 5,785K, the simulator spectrum lies 30 degrees above the AMO spectrum. The difference between the two spectra in the fractional emittance in the near uV band up to $\lambda = 300$ nm is only 0.1%. Thus it is insignificant. However, the deviation of the measured AMO spectrum from that of 5,785K blackbody in the near uV band is considerable and the simulator uV output may be twice as high as that of the AMO spectrum.

Figure 4 shows the first solar-pumped laser signals from the experiment obtained October 8, 1980. The first peak of the pulse train represents the laser power of a half watt. A total of six decreasing pulses with progressively longer intervals are observable, and conform to the peculiar iodine laser kinetics near the threshold. A germanium photodiode is used in the photovoltaic mode to record these laser outputs. The experimental set-up was later improved to have more precise synchronization and optical alignment. From October 24, 1980 laser outputs were repeatedly obtained. Figure 5 shows the typical laser output signal together with the solar simulator intensity variation (upper curve). The third curve on the bottom is the results of numerical simulation based on a laser kinetic model developed. The solar simulator peak output is approximately 4-kW (optical) and the peak laser output is 3 watt followed by 2-watt CW output. The lasing period is 1 ms. The lasing gas was 40-Torr $n\text{-C}_3\text{F}_7\text{I}$ and the risetime of the pumping light was 1 ms. With a remarkable accuracy the simulation results agree with the experiment.

Table 1 summarizes the pertinent parameters for the solar laser experiment. Note especially that the 4 kW_R beam power used is the amount obtainable from a small, 2-m dia. solar collector in space since the unit solar constant is 1.37 kW m^{-2} . The laser efficiency of 0.1% is half that of the theoretical maximum.

The importance of this breakthrough experiment is twofold: it is the first time a gas laser has been solar pumped, and its output is already comparable to the highest power ever achieved from any solar-pumped laser. Previously, a solid-state laser (neodymium) was solar pumped elsewhere at an output of about 5 watts, while our $\text{C}_3\text{F}_7\text{I}$ laser is producing pulses with peak power at 4.5 watts.

Figure 6 is the results with quasi-steady lasant flow as in a blow-down tunnel. The lasing at 30-Hz cycle was observed for 200 ms indicating that if continuous flow is maintained, the pulsed laser output can be obtained continuously. The decrease in the laser output with time in the Figure is mainly due to insufficient lasant flow speed to remove the quenching species such as I_2 , R_2 , etc.

Further details of the experiment are described in Publications 3 and 4. Appendix I is a reprinted copy of the publication 3.

* Table I. Solar Laser System Parameters.

Simulator Input Power	36 kW _E
Simulator Beam Output	4 kW _R
Equivalent Solar Collector	2 m Diameter
Laser Tube	7 mm Diameter x 40 cm Long Quartz
Effective Pumping Length	5 cm
Cavity Length	50 cm
Pumping Power	10,000 Solar Constants
Lasant	5-40 Torr C ₃ F ₇ I Vapor
Mirrors	M ₁ = 99.5% R, M ₂ = 98.0% R
Laser Output	4 Watts Peak Power
Lasing Period	1-10 ms
Laser Efficiency	1 x 10 ⁻³ (0.1%)
Theoretical Maximum	0.2%

(1 Solar Constant = 1.37 kW/m²)

III. IODINE LASER AMPLIFIER EXPERIMENT

Since the high power iodine solar laser system is expected to operate in a laser-amplifier mode, it is necessary to obtain the basic data for up-scaling the iodine laser amplifier. An array of HCP ultraviolet sources was used to pump an iodine laser amplifier to demonstrate its power amplification.

A Q-switch consisting of a Pockel's cell and a Glan prism was used for pulse chopping between the flashlamp pumped oscillator and the HCP pumped amplifier.

The preliminary results show that an on-off ratio of up to 4 is obtainable. The on-off ratio is the ratio of laser outputs through the amplifier medium when HCP pumping is either on or off.

It is expected that the ratio should increase to greater than 10 by further optimization of the system which is underway currently.

IV. LASER MHD GENERATOR

MHD energy conversion is known for high system efficiency, high-power density, and the closed cycle capabilities. These features are suitable for a solar-laser energy system proposed for energy conversion and power transmission in space. We have disclosed (see Invention Disclosure) a laser energy conversion system which couples the MHD generator with laser-produced plasmas.

Power transmission in space from a central power station to spacecraft, lunar base, or back to Earth is a feasible concept if lasers are used as the means of transmission. The small divergence of the laser beam (compared to microwaves) will considerably reduce the size of receivers required on the receiving system. Such a system requires a converter of high efficiency if the overall system efficiency is to be competitive with on-board systems.

Spacecraft are normally powered by on-board batteries or solar panels (i.e., solar cell arrays). Both methods increase the overall weight of the spacecraft and therefore the launch cost. Conversion of laser energy to electrical power has been restricted to terrestrial applications where the conversion is accomplished by solid state devices (Si or GaAs photoconverter) or by photoelectric devices (photomultiplier tubes, etc.).

The primary disadvantage of the prior art is the low conversion efficiency. These peak efficiencies are typically 15 percent for silicon detectors and 18 percent for GaAs. In addition, both of these devices are sensitive to the wavelength of the laser radiation so that in practical applications the efficiency may be lower. Photoelectric devices have peak efficiencies of less than 10 percent and are also wavelength-sensitive.

A schematic of the system is shown in Figure 8. The incoming laser beam to be converted is received by the receiving and focusing optics which focuses the beam to a small volume, thereby increasing the intensity. The plasma is produced at the entrance of the MHD channel by the high intensity of the focused laser beam. The plasma is produced in the flowing gas in the system (a plasma is a high temperature gas containing ions and free electrons). This gas is a mixture consisting of argon or another carrier gas (helium, krypton, xenon, etc.) which is seeded with a small percentage of an element with a very low ionization potential (potassium or cesium) to provide the ionization. The plasma that is produced expands through the MHD channel producing electrical power. A conventional MHD channel with electrodes and a magnetic field such as is used in commercial MHD power plants may be used. After expansion through the MHD channel, the cooled gas (plasma) goes to the gas separator system where the two gases are separated. The carrier gas then proceeds to the compressor where it is compressed and heated. The "seed" gas (potassium or cesium) is fed into the mixing chamber where it is heated to achieve the required density in the vapor phase and mixed with the carrier gas. The "seed" gas make-up supply to replace any seed gas lost during operation and the "make-up" supply for the carrier gas are also in the system.

The primary advantage of the invention over prior art is the potentially higher efficiency with which the laser energy is converted to electricity. The most efficient method existing in the previous art is the use of solid state photoreceptors which have conversion efficiencies of about 15 percent. This invention should have conversion efficiencies of at least 50 percent. A secondary advantage of the invention over the prior art is its independence of the wavelength of the incoming radiation. Methods employed in prior art are all wavelength-dependent.

While production of plasma by laser radiation and generation of electricity by the flow of plasma through an MHD channel are both known technologies, the combination of the two into a single system is believed to be a new concept and requires further study for its optimization. A preliminary modeling for estimating the efficiency of the system and an experiment (see Figure 9) with a 100-J CO₂ laser have been initiated at the Center.

V. FIGURES

- Fig. 1. Schematic of solar-pumped laser experiment.
- Fig. 2. Block diagram of the solar laser experimental set-up.
- Fig. 3. Color temperature of solar simulator beam.
- Fig. 4. The first solar-pumped laser signals, Oct. 24, 1981.
- Fig. 5. Comparison of experimental and numerical-simulation outputs.
- Fig. 6. Repetitively pulsed lasing at 30 Hz.
- Fig. 7. Threshold scaling.
- Fig. 8. Laser MHD generator concept.
- Fig. 9. Laser MHD generator experiment.

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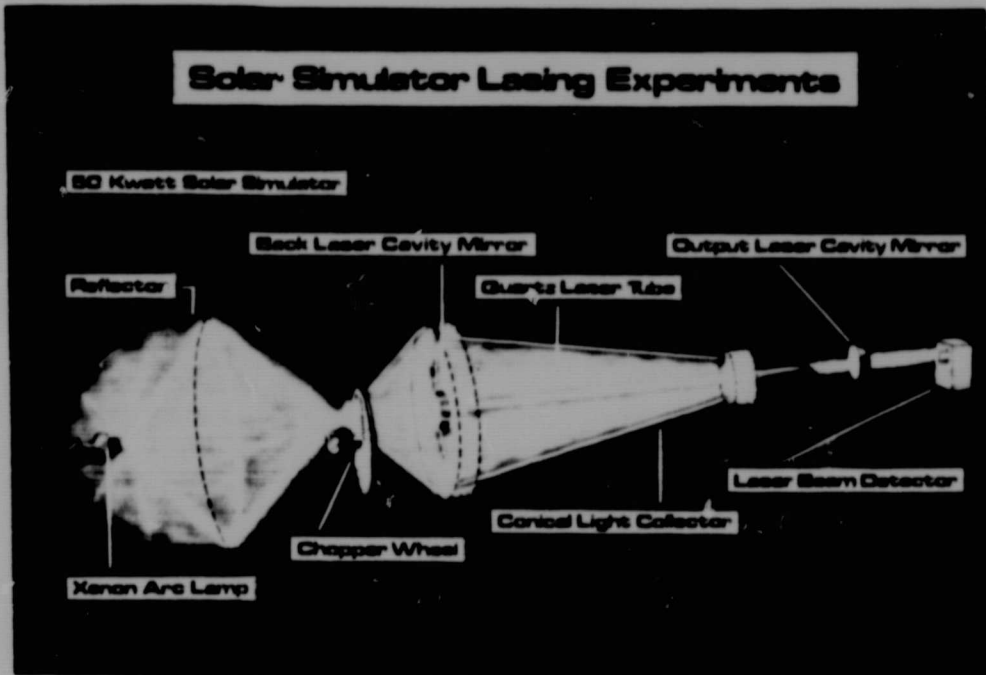


Figure 1. Schematic of Solar-Pumped Laser Experiment. A 50-kW solar simulator which has up to a 5-kW beam power output was used as the light source. The quartz laser tube was filled with $n\text{-C}_3\text{F}_7\text{I}$ vapor at 5-40 Torr pressure. The laser cavity was formed with two mirrors having 99.8% and 99.0% reflectivity at $\lambda = 1.3 \mu\text{m}$. The laser beam detector was a Ge diode at room temperature. An optical chopper wheel placed near the focus of the beam enabled pulsed operation of the laser system. The conical light collector is made of polished and coated aluminum.

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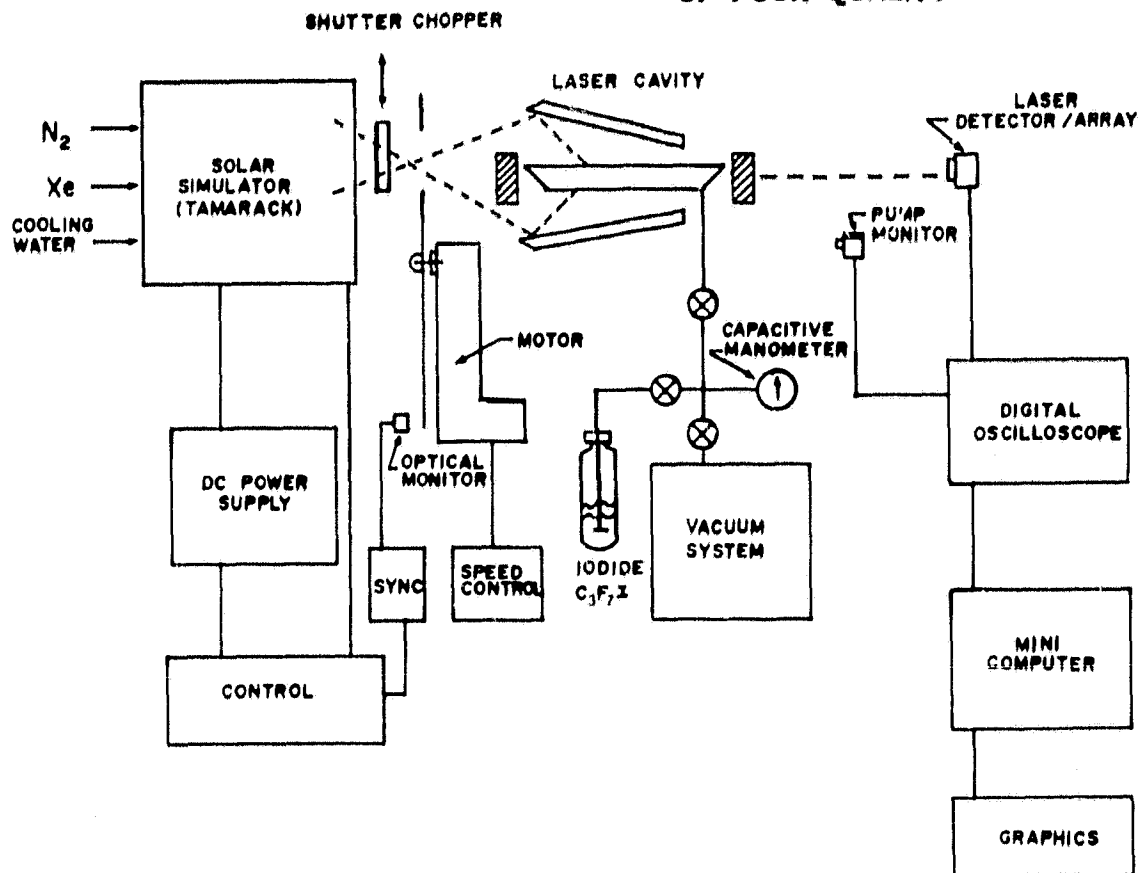


Figure 2. Block diagram of the Experimental Set-up. The solar laser experimental set-up consists of four subsystems; (1) a solar simulator and its power supply/control, (2) a variable speed optical chopper synchronized with the shutter of the simulator, (3) the laser cavity in an internally reflective cone with the gas handling lines, and (4) the laser detector coupled with data acquisition and processing instruments.

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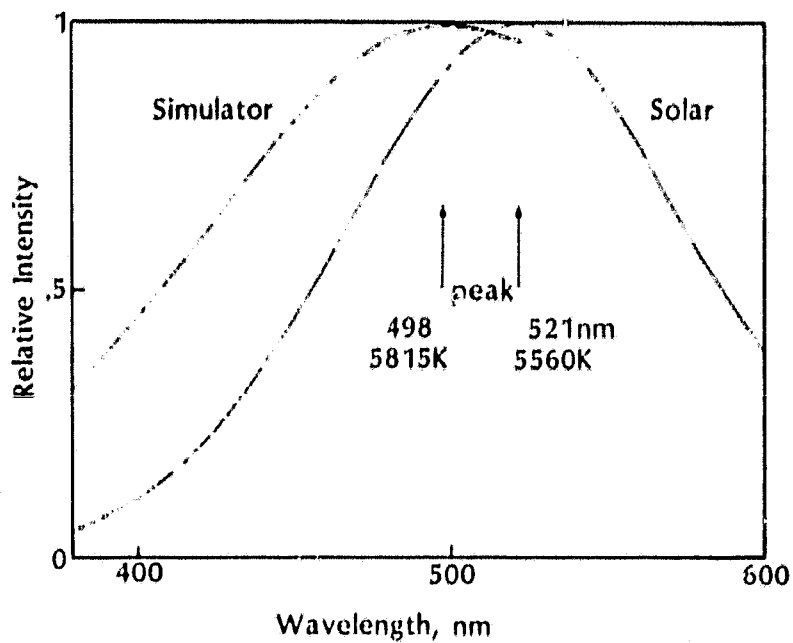


Figure 3. Color Temperature of Solar-Simulator Beam. The color temperature of the solar simulator beam was determined together with that of a noon-time solar spectrum near the laboratory in February, 1981. A reference carbon arc (not shown) was operated to obtain true intensity variations throughout the visible spectrum. A 1/2-m McPherson monochrometer with a photomultiplier was employed for spectral measurements.

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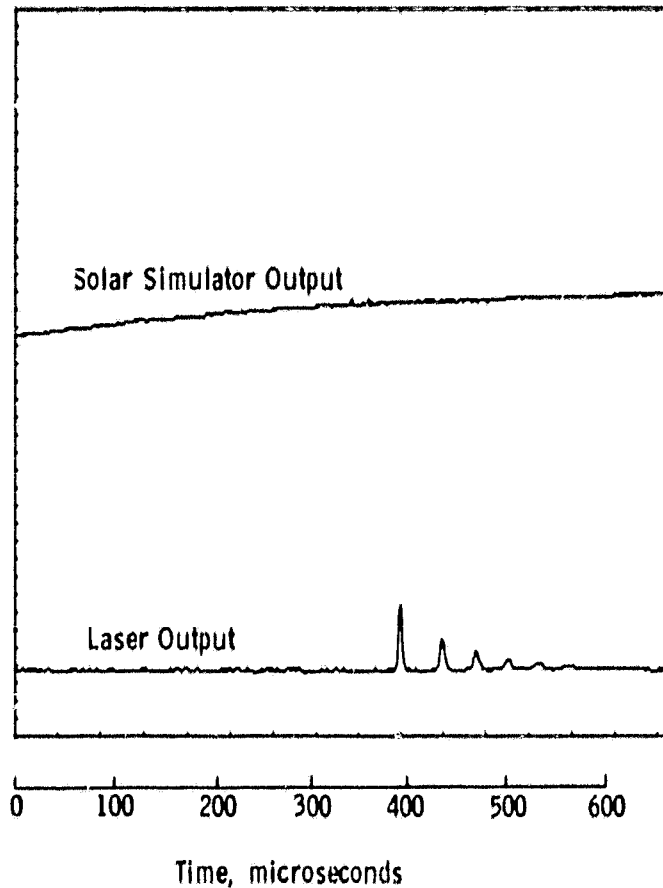


Figure 4. The First Solar-Pumped Gas Laser Signals. The iodine laser output at $\lambda = 1.315 \mu\text{m}$ were obtained on October 8, 1980. This event was the first experimental demonstration of a solar-pumped gas laser. The first peak of the pulse train represents the laser power of a half watt. Six decreasing pulses are observable. A Ge photodiode was the laser detector.

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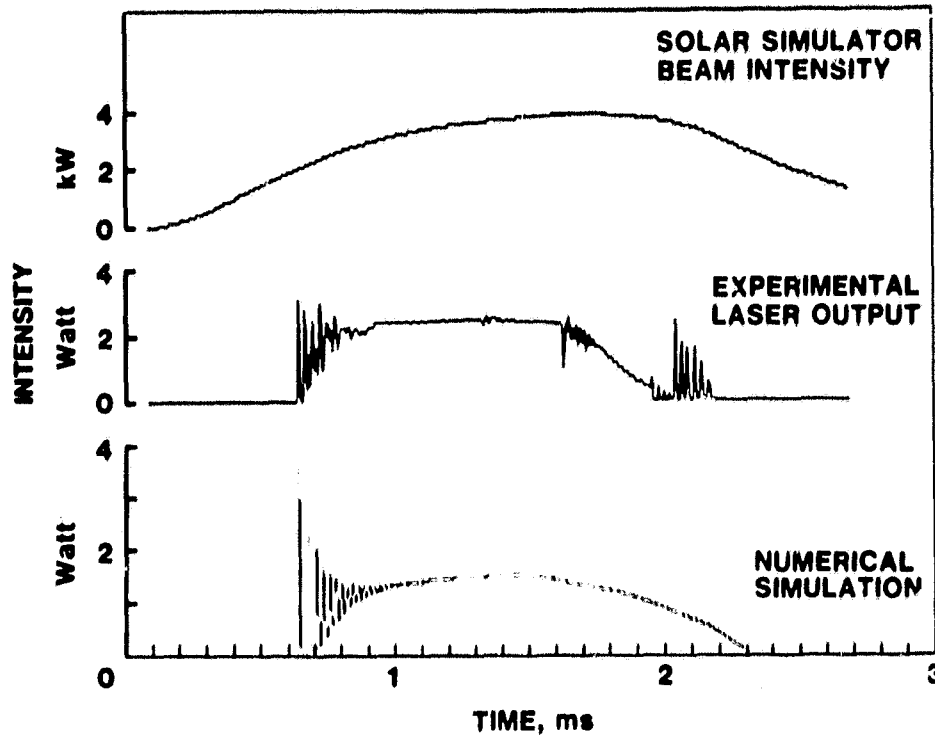


Figure 5. Comparison of Experimental and Theoretical Output for the Solar-Pumped Iodine Laser. The experimental (center trace) and the theoretical laser (lower trace) outputs are compared together with the solar simulator beam intensity (upper trace). General agreement between two traces is apparent.

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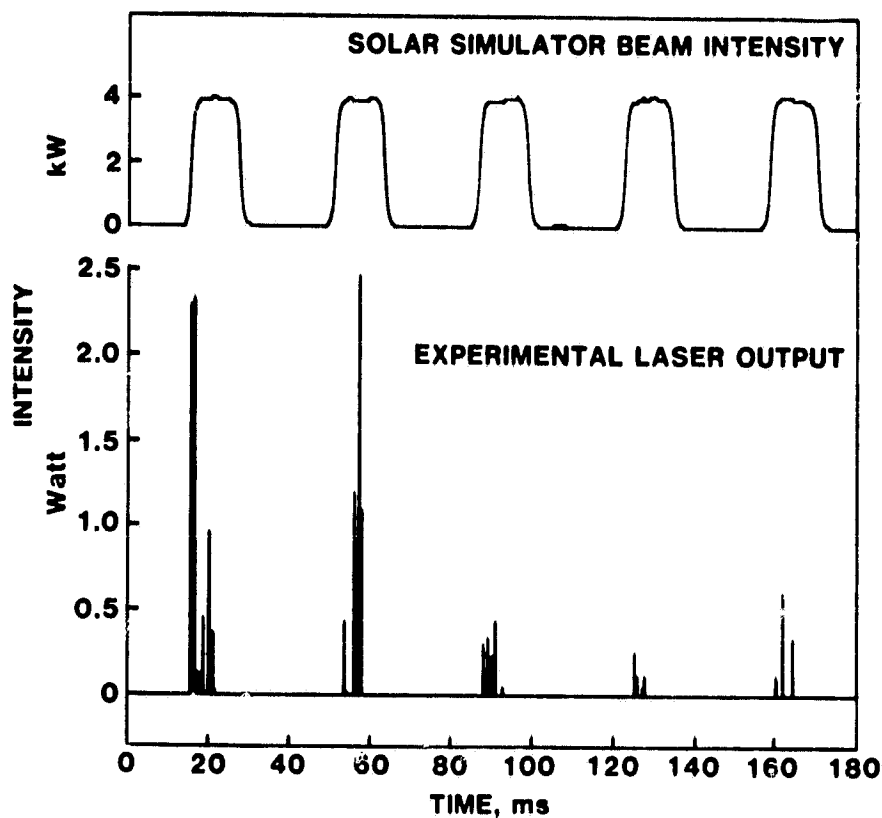


Figure 6. Repetitively Pulsed Lasing at 30 Hertz. The lasing was observed for 200 ms continuously at 30 Hz when the lasant flow was maintained by a "blowdown" method similar to one often used in a wind tunnel experiment. The flow removes the quenching species that are produced by lasing.

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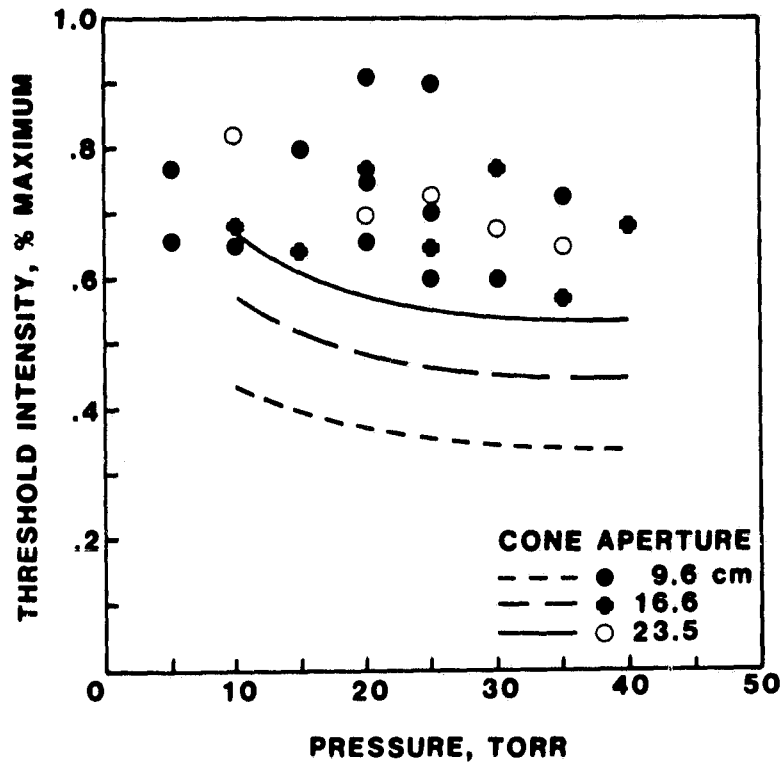


Figure 7. Threshold Power Scaling. The three curves in this figure show the predicted threshold power scaling law dependence for three cone sections obtained from the time-dependent equations. The three cone segments intercept the simulator beam to give the varieties in pump length and solar concentration. The vertical scale is the percent of maximum beam power from the simulator at which lasing was initiated, a parameter directly related to threshold inversion density and solar concentration. The circles and crosses are the experimental results as indicated. The factor-of-two discrepancy between theory and experiment is not unexpected in this parameter, but the scatter in the experimental data results from arc flutter in the Tamarack simulator lamp.

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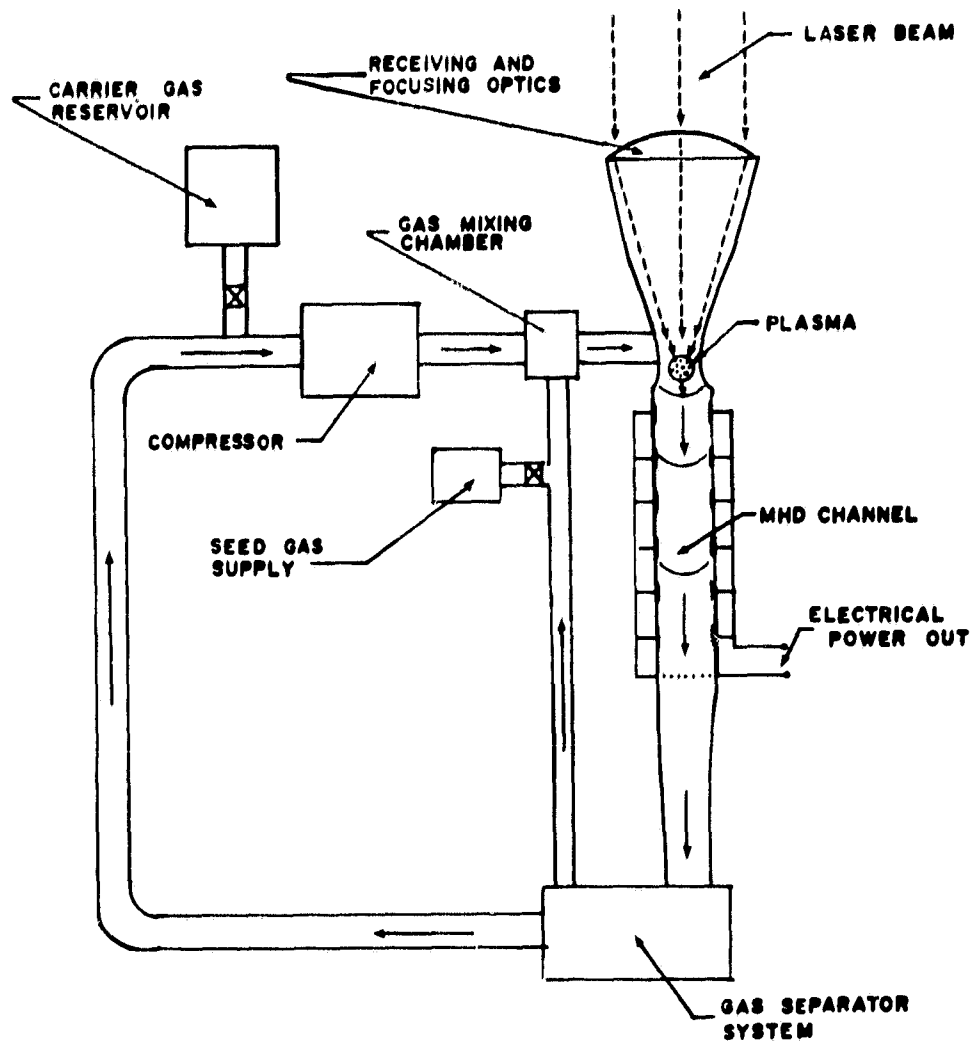


Figure 8. Laser MHD Generator Concept. The generator consists of beam receiving focusing optics and a plasma MHD generator. The working fluid is a mixture of an inert gas and an alkali seed gas. The seed gas is used for lowering ionization potential which increases the plasma conductivity. The MHD generator cycle is similar to a conventional coal-fired MHD cycle except the coal combustor is replaced by the beam receiving/focusing optics.

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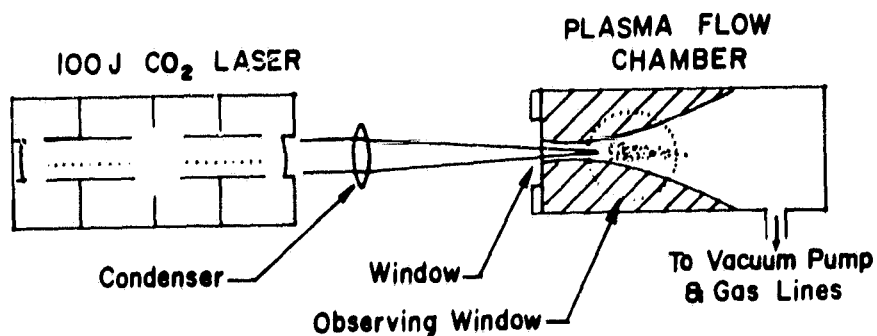


Figure 9. Laser MHD Generator Experiment. The plasma flow chamber consists of a unidirectional nozzle, an infra-red window and a diffusing volume. The observing window is made of transparent material and provides access for flow velocity and spectroscopic measurements. Probes to be used for conductivity measurement are not shown.

VI. PUBLICATIONS

Journal Publications and Reports

1. J. H. Lee, D. R. McFarland, and F. Hohl, "Ultraviolet Laser Excitation Source", Applied Optics 19, 3343 (1980).
2. J. W. Wilson and J. H. Lee, "Modeling of a Solar-Pumped Iodine Laser", Virginia J. of Science 31, 34 (1980).
3. J. H. Lee and W. R. Weaver, "A Solar Simulator-Pumped Atomic Iodine Laser", Applied Phys. Lett. 39, 137 (1981).
4. W. R. Weaver and J. H. Lee, "A Solar Simulator-Pumped Gas Laser for the Direct Conversion of Solar Energy", Proceedings of 16th Inter-society Energy Conversion Engineering Conference, August 9-14, 1981, ASME, Atlanta, GA, p. 84.
5. J. H. Lee and F. Hohl, "Solar Driven Liquid Metal Magnetohydrodynamic Generator", NASA TM 81965, May 1981.
6. J. H. Lee, D. R. McFarland, and R. J. DeYoung, "Fluorine Laser Pumped by a Hypocycloidal-Pinch Array", J. Opt. Soc. Am. 70, 1621 (1980).
7. J. H. Lee and D. R. McFarland, "Spectral Enhancement of Near Ultraviolet Emission from Hypocycloidal-Pinch Plasmas", Bull. Am. Phys. Soc. 25, 1010 (1980).
8. J. H. Lee and W. R. Weaver, "A Solar-Pumped Gas Laser", Technical Digest, Conf. on Lasers and Electro-Optics 81, June 10-12, 1981, IEEE/OSA, Washington, D.C., p. 84.
9. J. H. Lee, "Intense Electron Beam Generation and Laser Excitation by Plasma Focus Discharges", The Second International Workshop on Plasma Focus Research and Related Phenomena", Sept. 21-23, 1981, Moscow, USSR (submitted).

VII. INVENTION DISCLOSURES

1. Direct Excitation by Solar Radiation of a Gas Laser

Ja H. Lee, F. Hohl, and W. R. Weaver

Disclosure Date: September 30, 1981

NASA Case No. 12870-1, US Patent Pending, 1981

Abstract

The direct conversion of broadband, incoherent solar radiation into coherent laser radiation using a gaseous lasing medium has been accomplished. The prior art used a solid-state, Nd^{3+} :YAG or Ruby laser for solar pumping. However, the power output of a solid-state laser is limited by an inability to cool the solid laser rod. A proof of principles of the invention has

been demonstrated by successful excitation of a 4-W iodine laser with simulated solar radiation. The same principles and methods could be applied to other gas phase lasants such as iodine bromide, nitrosil chloride and further to liquid phase lasants (see Figure 1).

2. Laser-Driven MHD Generator for Conversion of Laser Energy to Electricity

N. Jalufka and Ja H. Lee

Disclosure Date: February 6, 1981

NASA Case No. 12859-1, US Patent Pending, 1981

Abstract

The invention proposes the conversion of laser energy into electricity at high efficiencies by using the magnetohydrodynamic (MHD) generator principle. The prior method uses a solar panel as laser power receiver and converter. Therefore, the prior method is sensitive to the wavelength of the laser radiation and the efficiency is limited by that of the solar panel, typically less than 15 percent. The invention combines production of plasma by high power laser radiation and generation of electricity by the flow of the plasma through an MHD channel into a single system (see Figure 10).

VIII. ACTIVITIES

Conferences Attended

Optical Society Annual Meeting, Chicago, IL, October 13-17, 1981

Paper presented: "Atomic Fluorine Laser Pumped by Hypocycloidal-Pinch Array".

Topical Meeting on Infrared Lasers, Los Angeles, CA, December 3-5, 1980.

Conference on Lasers and Electro-Optics (CLEO 1981), Washington, D.C., June 10-12, 1981.

Paper presented: "Solar-Pumped Gas Laser".

Appendix 1

A solar simulator-pumped atomic iodine laser

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(Received 16 March 1981; accepted for publication 30 April 1981)

An atomic iodine laser, a candidate for the direct solar-pumped gas laser, was excited with a 4-kW beam from a xenon arc solar simulator. Continuous lasing at $1.315 \mu\text{m}$ for over 10 ms was obtained for static filling of $n\text{-C}_3\text{F}_7\text{I}$ vapor. By momentarily flowing the lasant, a 30-Hz pulsed output was obtained for about 200 ms. The peak laser power observed was 4 W for which the system efficiency reached 0.1%. These results indicate that direct solar pumping of a gas laser for power conversion in space is indeed feasible.

PACS numbers: 42.55.Hq, 42.60.By, 84.60.Rb

The concept of collecting and converting solar energy to high-power lasers has stimulated studies of various laser systems and their applications. Important applications considered include laser propulsion of space- or air-borne vehicles and laser power transmission to remote spacecraft from a space platform. Also laser power transmission is an alternative to the microwave power transmission from the Space Power System (SPS) that was under consideration by NASA. The use of lasers in space for power transmission has an obvious advantage because of small beam divergence, resulting from wavelengths that are smaller by $\approx 10^4$ than that of microwaves.^{1,2} However, space deployment places special requirements on the laser system. Important are (i) a gas or liquid phase lasant to effect continuous cooling and recharging for high-power ($> 1 \text{ MW}$) operation (ii) high temperature operation to reduce cooling requirements; (iii) chemical reversibility to renew the lasant in space and (iv) broadband

pumping to efficiently use the solar spectrum. Although power transmission by conventional lasers is possible with electric power generated in space, the direct solar-pumped laser offers the further advantage of weight reduction by elimination of the electrical power generator. However, experimental and theoretical research is lacking in the identification of a suitable laser system in which incoherent solar photon flux is directly and efficiently converted to coherent laser beams.³

This letter reports the first "solar pumping" of a gas laser which meets the requirements for space deployment and has the potential for scaling to high power levels. An iodine photodissociation laser at $1.315 \mu\text{m}$ was chosen as the solar laser candidate, and a xenon arc solar simulator (made by Tamarack) which provides 4-kW beam power was used for optical pumping. The spectrum of the beam resembles the air mass zero solar spectrum with an average spectral deviation of 20%. The effective pumpband for the lasant, $n\text{-C}_3\text{F}_7\text{I}$, is in the near ultraviolet at 250–290 nm, which amounts to 1% of the total solar insolation (Fig. 1). The upper level I ($5^2P_{1/2}$) of the iodine laser transition is produced by photolysis of the lasant perfluoropropylidide:

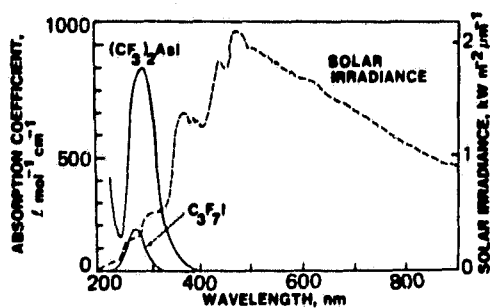


FIG. 1. Absorption curves of perfluoropropylidides and the air mass zero solar spectrum. The overlap of the curves is such that $n\text{-C}_3\text{F}_7\text{I}$ can absorb up to 1% of the total insolation in the near ultraviolet range. If $(\text{CF}_3)_2\text{AsI}$ is the lasant, as much as 7% absorption is possible.

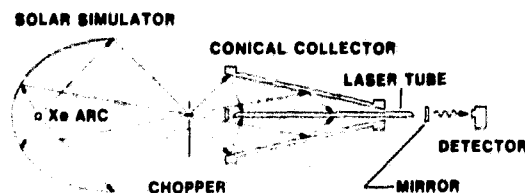


FIG. 2. Schematic of experimental apparatus for direct solar-pumped gas laser.

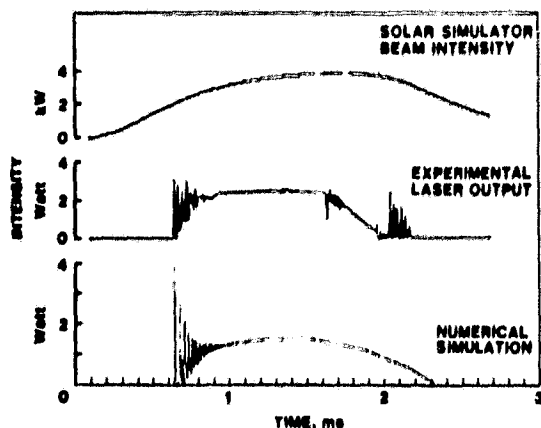


FIG. 3. Comparison of the solar simulator output (upper), the iodine laser signal (center), and the results of a numerical simulation (lower).

$C_3F_7I + h\nu \rightarrow C_3F_7 + I(5^2P_{1/2})$, and the lower level is the ground state of the iodine atom $I(5^2P_{3/2})$. Numerical simulation based on known kinetics of the iodine laser was developed to compare to the experimental results.⁴ In earlier research on this lasant, the threshold inversion density of about 10^{15} cm^{-3} was measured, and lasing was achieved at elevated temperatures up to 670 K with a xenon flashlamp as the pump source.⁵

For the present experiment, a 7-mm i.d. quartz tube was filled with normal perfluoropropyl iodide and irradiated side-on by converging beams from a conical aluminum collector, which was placed in the simulator beam, to produce a 5-cm focal line on the axis of the quartz tube (see Fig. 2). The average pumping intensity at the tube's surface was measured with a foil calorimeter as 10 000 solar constants (1 solar constant equals to 1.35 kWm^{-2}). A variable-speed optical chopper was placed near the focus to obtain pulsed pumping to minimize quenching. The laser cavity was formed with two dielectric mirrors, one of which had 2% transmission for the laser output which was monitored with a Ge detector at room temperature. The beam profile measurement with an InAs detector array gave a 4-mm-diameter spot size. A typical laser signal is shown in Fig. 3 together

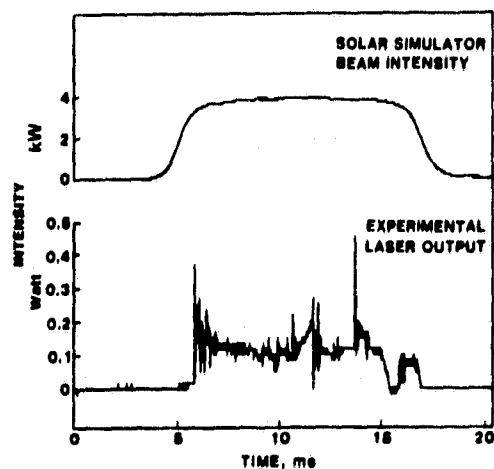


FIG. 4. Continuous lasing of C_3F_7I for over 10 ms for single static filling.

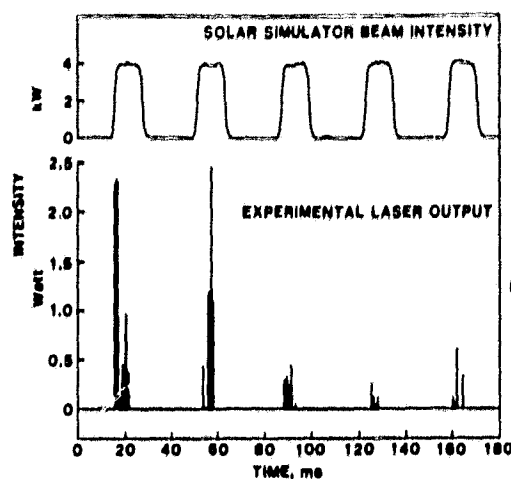


FIG. 5. 30-Hz pulsed C_3F_7I laser output with the lasant flowing in a blowdown wind tunnel.

with the simulator output signal (upper trace) and a result of the numerical simulation (lower trace). The lasing lasts for 1.6 ms with the peak power of approximately 3 W. The output power was determined with the detector's absolute calibration data and the spot size from the beam profile measurement. The threshold of lasing is reached when the solar simulator output increases to about 50% of maximum intensity. The initial spikes and subsequent continuous output ($\approx 2 \text{ W}$) of the experimental results agree well with those of the numerical simulation. The highest laser output recorded on other tests exceeded 4 W, which is comparable to the maximum output (5 W) of the well-developed solid-state Nd^{3+} :YAG solar laser.⁶ For the highest laser output of the present research, the system efficiency is 0.1%, which is one-half of the maximum intrinsic efficiency. Continuous lasing was obtained for over 10 ms at reduced fill pressure and an extended pump period (Fig. 4). When the lasant was flowed through the laser tube as in a blowdown wind tunnel, a 30-Hz pulsed output was observed for as long as 200 ms (see Fig. 5). The decrease of the laser output with time in Fig. 5 is mainly due to insufficient flow speed.

Figure 6 shows the variation of the laser output as a function of lasant pressure. The pressure range from 2 to 3.3

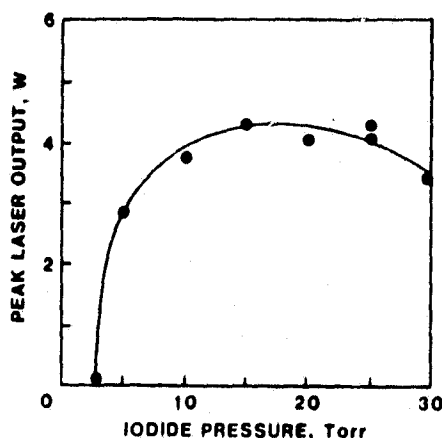


FIG. 6. Laser output as a function of C_3F_7I lasant pressure.

kPa (15–25 Torr) produced the maximum laser output, a result which also agrees well with the numerical simulation result of 2 kPa.

The experimental results presented here are significant because the lasant is in a gaseous form which can be circulated for external cooling and reprocessing. The iodine laser is a high-power laser which has already been developed to terawatt levels as a laser-fusion driver⁷ indicating virtually unlimited scalability, and the lasing wavelength of $1.315\ \mu\text{m}$ allows the use of well-developed optical materials for high-power infrared lasers. Furthermore, the iodine laser can be operated in a high-temperature (up to 700 K) environment, which significantly reduces cooling requirements in space.

Two factors limiting the laser output of the present experiment are power input and mismatch between the lasant absorption band and the peak of the solar spectrum. The first factor is not a limitation in space where a large solar collector could be placed. Indeed, the beam power used in the experiment could be collected with only a 2-m-diam collector. The second factor can be improved with an alternate iodide⁸ such as $(\text{CF}_3)_2\text{AsI}$, which absorbs seven times the amount of the solar spectrum as the $\text{C}_2\text{F}_7\text{I}$ (see Fig. 1). In addition, the reduced output in successive pulses (Fig. 5) of the present laser can be overcome by a closed-cycle system that removes the accumulated I_2 and replenishes the iodide consumed, the two causes of quenching.⁹

In summary, a gas laser was pumped for the first time

using simulated solar insolation. Output powers up to 4 W and continuous lasing over 10 ms were obtained for a static fill. The solar-pumped iodine laser, which can be scaled up to a high power level, possesses significant advantages over existing schemes for solar power conversion in space.

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